U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center

Klamath Natural Flow Study RiverWare Mass Balance Modeling

Model Purpose

The purpose of the Natural Flow Study RiverWare Mass Balance Model is to integrate modeled surface runoff, groundwater contributions to streamflow, consumptive use, open water evaporation, and hydraulics and to develop estimates of unimpaired streamflow, assuming pre-development conditions of the early 1900s. The Mass Balance Model calculates streamflow based on differences in various inflows (e.g., surface runoff, groundwater contributions to streamflow, drain flows, etc.) and losses (diversions, open water evaporation, etc.) based on their modeled post- and pre-development contributions. This model also removes the effects of infrastructure (e.g., Link River Dam, Klamath Project diversions, etc.) throughout the Klamath River basin upstream of the Klamath River confluence with the Trinity River. To simulate Natural Flow the following features are modified:

- Lakes and Reservoirs returned to natural state
- Diversions, drains, returns, and inter-basin transfers removed
- Hydraulic connections between the Lost River and Klamath River, as well as Lower Klamath National Wildlife Refuge area and Klamath River, returned to natural state

Model Selection and Input Data

The Mass Balance Model uses RiverWare, a modeling framework calculates the water balance of a managed water resources systems using a prioritized list of policy statements and tailored methods for river and reservoir routing, among others. Figure 1 (conceptual diagram; backside) includes a list of input data and sources.

Natural Flow Representation

To simulate natural flow (pre-development) conditions, the Mass Balance Model will combine observed gaged streamflow with the observed modeled inputs/outputs from the complimentary models (e.g., surface runoff, etc.). This is done primarily using two methods:

1. **Simulation:** In this approach, the Mass Balance Model is calibrated under current (post-development) conditions by comparing simulated streamflow at gage locations to observed (measured) streamflow at those locations. Natural streamflow is estimated by removing current condition features (such as dams, levees, diversion structures) and consumptive use and adding pre-development consumptive use (based on native vegetation).

2. **Difference:** In this approach, differences between inflows to (or losses from) the Klamath River and major tributaries under pre-development and current conditions are calculated. Natural Flow will be estimated by adjusting observed (measured) streamflow by the calculated differences.

In both approaches, operating rules are developed within RiverWare to reconcile differences in reservoir/lake and channel characteristics for the current condition and the pre-development condition. The approaches will be further refined as contributing model components come closer to completion.

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Uncertainty Analysis

The RiverWare model will be run using both approaches and with multiple potential combinations of inputs from related modeling components based on uncertainty bounds in each component. Multiple RiverWare modeling parameterizations may also be represented, resulting in an ensemble of daily natural streamflow estimates at desired locations. Ensemble mean/median natural streamflow and uncertainty bounds will be provided in the final natural streamflow dataset.

Model Products

Estimate natural streamflow for the following locations (Table 1):

Table 1. Summary of estimated natural flow locations

USGS ID	Description
11501000	Sprague River near Chiloquin, OR
11502500	Williamson River below Sprague River near Chiloquin, OR
11507500	Link River at Klamath Falls, OR
11504115	Wood River near Klamath Agency, OR
11509500	Klamath River at Keno, OR
11510700	Klamath River below JC Boyle Powerplant near Keno, OR
11516530	Klamath River below Iron Gate Dam, CA
11517500	Shasta River near Yreka, CA
11519500	Scott River near Fort Jones, CA
11520500	Klamath River near Seiad Valley, CA
11523000	Klamath River at Orleans, CA
Not Applicable	Klamath River at Weitchpec, CA

Key References

University of Colorado, RiverWare Version 8.5 User Documentation. 2022. Available online: https://www.riverware.org/HelpSystem/8.5-Help/index.html (accessed on 24 June 2022).

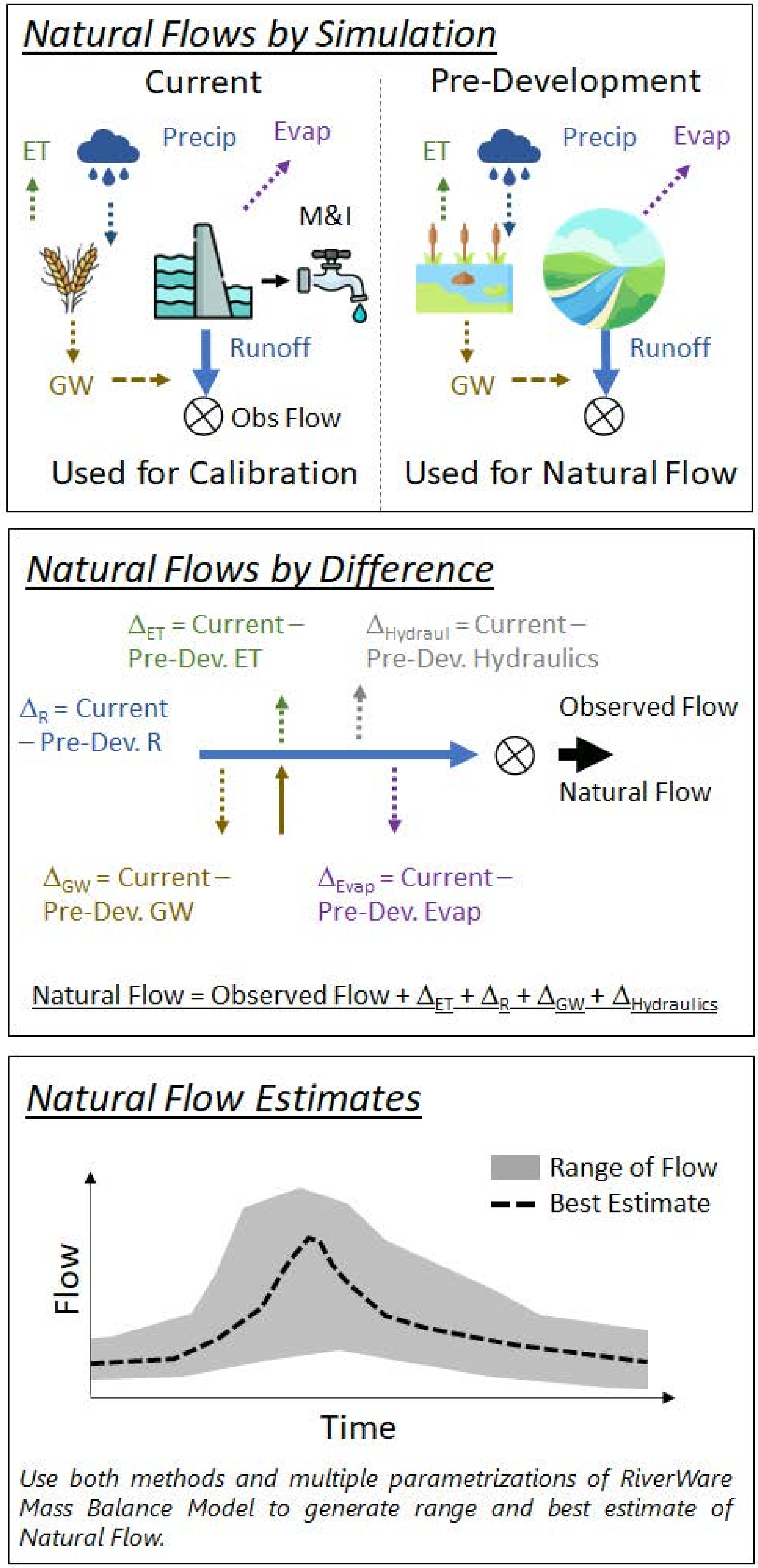

Figure 1. Mass Balance Modeling Approaches for developing Pre-Development (Pre-Dev) Natural Flow using Observed (Obs) flow and simulated variables: Runoff (R), Groundwater (GW), Evapotranspiration (ET), open water Evaporation (Evap), Precipitation (Precip), Hydraulics (Hydraul), and Municipal and Industrial (M&I)